Productivity Growth without Technical Change in European Agriculture before 1850

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Output per farm worker in the northern United States and Britain in the early nineteenth century was many times that in Eastern Europe or in medieval England and wages were correspondingly higher. Technical progress explains little of the high American and British productivity in the early nineteenth century, nor, in the American case, does abundant land per worker. Instead, most of the difference derived from more intense labor in America and Britain.

Farm workers in the northern United States and in Britain in the early nineteenth century were extraordinarily productive and well paid by the standards of Eastern Europe and of medieval England. Paul Bairoch, for example, estimates that output per worker in the United States in 1840 was about three times that in Austria, Germany, or Russia, but only about 23 percent more than in Britain.[1] In confirmation of this estimate, on two large lordships with an area of 119,000 acres in the province of Lublin, Poland, in 1825 each male farm worker produced only 70 bushels of grain per year.[2] Bohemia was an area of more advanced agriculture, yet even there a large manor of 28,000 acres devoted mainly to grain production had an output of only 130 bushels of grain per male worker in 1841.[3] In the northeastern United States in 1850 there were about 28 acres of farmland per male agricultural worker.[4] If even half this land was sown in grains in any year, the output per worker would have been 308 bushels, which is more than four times

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[1] See Paul Bairoch, "Agriculture and the Industrial Revolution, 1700–1914," in Carlo Cipolla, ed. *The Fontana Economic History of Europe* (New York, 1976), vol. 3, p. 472.

[2] William Jacob, *Tracts Relating to the Corn Trade and Corn Laws: including the Second Report* (London, 1828), First Report, pp. 96–99.

[3] Jerome Blum, *Noble Landowners and Agriculture in Austria, 1815–1848* (Baltimore, 1948), pp. 167–70.

[4] U.S. Bureau of the Census, *Historical Statistics of the United States* (Washington, D.C., 1976), Part 1, pp. 24–37, 460. The Northeast comprises New England, New York, New Jersey, and Pennsylvania.

the Polish output.[5] Even in Britain, where there was considerable animal husbandry, each male worker in 1841 produced 216 bushels of grain, three times the Polish output.[6]

The average family in the late thirteenth century in England tilled about 21 acres of land (14.0 acres of their own, 7.0 acres of the demesne).[7] Family size in the middle ages is disputed, but a survey of Lincolnshire in 1267/68 showed 4.7 persons per household.[8] This implies 1.65 male workers per household, assuming that 70 percent of males were of working age. Even if peasants achieved the yields of thirteenth-century English demesnes, this implies an output of only 90 bushels per worker, about the same output as in Poland in the early nineteenth century, but only a half to a third of output per worker in Britain or the north of the United States.[9]

Corresponding to these high outputs per worker were high wages in America and Britain. Wages of farm workers in Pennsylvania and New York in the 1820s, when these were major grain-producing areas in America, were $0.62 and $0.50 per day respectively; wages in Massachusetts were $0.81 per day.[10] British farm workers in 1850 earned about $0.40 per day.[11] In Eastern Europe even those workers in the free labor market in the 1820s received extraordinarily low wages: $0.10 per day in Prussia and $0.08 per day in Poland.[12] If calculated in bushels of wheat, wages in America still ranged from 0.56 to 0.89 bushels per day, while those in Prussia and Poland ranged from 0.12 to 0.14 bushels per day, only one-fifth the American wages. Interestingly, the wage of medieval English ploughmen prior to 1349 was equivalent to about 0.11 bushels per day, which is not much less than that of Polish peasants in the 1820s.[13]

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[5] The wheat yield per acre in the northeastern United States in the 1840s was about 16 bushels per acre, and the oats yield about 28 bushels per acre. See William N. Parker and Judith L. V. Klein, "Productivity in Grain Production in the United States 1840–60 and 1900–10," in National Bureau of Economic Research, *Output, Employment and Productivity in the United States After 1800*, Studies in Income and Wealth, 30 (New York, 1966), pp. 548–52.

[6] See Gregory Clark, "The Agricultural Revolution in Britain, 1661–1841: Changes in People versus Changes in Technique" (unpublished manuscript, Stanford University, 1987).

[7] E. A. Kosminsky, *Studies in the Agrarian History of England in the 13th Century* (New York, 1956) pp. 100, 216, 223.

[8] H. E. Hallam, "Population Densities in Medieval Fenland," *Economic History Review*, 2nd ser., 14 (1961).

[9] Such yields are given in J. Z. Titow, *Winchester Yields: A Study in Medieval Agriculture Productivity* (Cambridge, 1972).

[10] Percy W. Bidwell and John I. Falconer, *History of Agriculture in the Northern United States, 1620–1860* (Washington, D.C., 1925), pp. 205–6; U.S. Department of Labor, *Thirteenth Annual Report of the Commissioner of Labor* (Washington, D.C., 1899), vol. 2, pp. 433–73.

[11] *Gardener's Chronicle and Agricultural Gazette*, 27 Apr. 1850, pp. 266–67.

[12] Jacob, *Tracts*, First Report, pp. 19, 96–99, 132–35.

[13] The annual wages of ploughmen on a number of manors can be calculated from James E. Thorold Rogers, *A History of Agriculture and Prices in England* (Oxford, 1866), vol. 1, pp. 245, 288–89, vol. 2, pp. 329–34.

The greater outputs of American and British farm workers in the early nineteenth century had to stem from some combination of technical progress, land abundance, soil quality, and the amount of labor input per worker. I show below that the greater intensity with which American and British workers performed ordinary farm labor was the major explanation of why output per worker and wages were high in America and Britain.

It is commonly accepted that output per worker and wages were high in American agriculture because of the relative abundance of land. Percy Bidwell and John Falconer, for example, explain high American wages as "the conditions commonly found in new countries resulting inevitably from the cheapness of land."[14] Land abundance, however, explains little of the output and wage differential. As noted above, there were about 28 acres per male worker in the northeastern United States in 1850. On the crown lands of the kingdom of Poland in 1825, which comprised one-third of the country, there were about 23.5 acres of farmland per male agricultural worker.[15] More exact figures for four large manors in western Poland and eastern Russia, covering together 600,000 acres, also show 23 acres of farm land per male worker.[16] Suppose the only difference between Polish and American agriculture in the early nineteenth century was 22 percent more land per worker in America. Then at most, output per worker would be 22 percent higher in the northeastern United States, rather than the 300 percent differential observed.

In line with the above, the collective burdens on the land in Poland—land rents, taxes, and tithes—were less than $0.64 per acre in both Prussia and Poland in the 1820s, or about one bushel of wheat at local prices.[17] In 1850 the average rental of farmland in the northern United States was equivalent to 0.60 bushels of wheat.[18] This implies that had land been more abundant in Poland, so that each worker cultivated as much land as in the northeastern United States, and had the landlords collected only the same rent as in America, Polish wages would have been increased by at best 54 percent, a small proportion of the 400 percent advantage observed.[19] Britain had less land per agricultural worker, and rents per acre were about three times those in Poland, so that land abundance played no possible role in explaining high British wages and outputs per worker.

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[14] Bidwell and Falconer, *History of Agriculture*, p. 33.

[15] Jacob, *Tracts*, First Report, pp. 32, 37. Jacob reports that the crown lands had about 8 million acres of mainly arable farmland, and one-quarter of the population of the kingdom.

[16] Ibid., pp. 14, 20, 32–33, 36, 97, 133–37.

[17] The total burden on the land in Poland in the 1820s consisted of three elements; about $0.24 of rent per acre, $0.06 of taxes, and the tithe of one-tenth or less of gross output (Jacob, *Tracts*, First Report, pp. 32–36, 99). Output per acre of tillage land in one large lordship in Poland was about $2.68 of grain, plus an unspecified value of fodder in the straw and fallow grazing. Assuming conservatively that the fodder was worth a quarter of the grain, the value of output per acre was $3.35 (Jacob, *Tracts*, First Report, pp. 97–99). Thus the total burden on the land was only about $0.64.

[18] The rental value for the United States is derived by taking 4 percent of the value per acre recorded in the 1850 census (U.S. Bureau of the Census, *Historical Statistics*, pp. 460–62).

The main source of high American and British outputs per worker was, it seems, high yields per acre compared with Eastern Europe. This appears to imply that the foundation of American and British farming prosperity was the use of advanced agricultural techniques, since there is no evidence that the soil quality in the northeastern United States or Britain was inherently any higher than that of the rest of Northern Europe.[20] But while advanced techniques explains higher yields per acre, it cannot explain the higher output per worker in America and Britain, since in grain farming most of the labor inputs were proportional not to the area of land farmed but to the output. In particular, as is shown below, labor inputs per acre in threshing, harvesting, and manuring were proportional to yields per acre. These operations constituted two-thirds of the labor inputs in raising grain crops.

The labor requirements of harvesting are particularly important, since labor inputs in both the agriculture of the northern United States and of Northern Europe peaked sharply at the harvest. Thus the constraint on output per worker was the amount of grain that could be harvested per worker in the harvest period.[21] I show below that even where the same harvest technique was used, American and British workers were able to perform the work many times as quickly as in Eastern Europe or medieval England.

LABOR INPUTS, YIELDS, AND PRICES

The tasks used to compare labor intensity are the threshing of grains such as wheat, barley, and oats, and the reaping of wheat. It is important to establish that labor inputs in these tasks were independent of crop yields per acre and of the relative prices of grain and labor, since yields and wage rates varied across countries.

In the early nineteenth century in areas of advanced agriculture the higher yields of grain crops stemming from new rotations, manure applications, and more careful cultivation seem to have resulted largely from more of the same plants being grown per acre. Wheat and barley were grown on unmanured plots and on plots with farmyard manure at the Rothamsted experimental station from 1841 onwards. The manured wheat yielded three times the 12.6 bushels of the unmanured, while the manured barley yielded about twice that of the unmanured. But the ratio of the weight of grain to that of straw varied little with the yield, and was in fact 10 to 20 percent higher with the low-yielding unmanured crops.[22] Also, the number of grains per bushel of wheat was the same for a yield of 39.2 bushels per acre as it was for a yield of 12.3 bushels per acre, so the individual grains were not getting bigger.[23] And Henry Stephens notes in passing that a stem of wheat commonly bears an ear of 32 grains, which implies that the number of stems of straw per bushel of grain remained the same with higher yields.[24]

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[19] If Polish rents were reduced to American levels, the residual per acre left to pay wages would increase by about 27 percent. Combining this with 22 percent more acres of land tilled per worker gives the maximum possible increase in wages with greater land availability as 54 percent.

[20] J. Papadakis, *Soils of the World* (Amsterdam, 1969), classifies most of the soils in the northeastern United States as naturally acid and infertile podsols. British soils are also principally infertile podsols.

[21] I am grateful to Ester Boserup for this important observation.

Albert Thaer gives a ratio of one to two for the weight of wheat grain to that of straw for the low yields of Prussia, which is about the same as the Rothamsted ratio and as the ratio given for the high yields of Britain in 1840 reported by J. R. McCulloch.[25]

If all that was happening with denser crops was that the plants were closer together, in threshing there would be no labor saving with higher yields. In harvesting the savings would be very limited, since most of the labor involved cutting the stems, binding and stacking the cut grain, and carting the sheaves to the barn. With higher yields a reaper had to cover less ground per bushel, but in reaping wheat, for example, at yields of 26 bushels per acre, a British reaper in the nineteenth century would walk less than one mile in cutting the wheat.[26] Consequently the famous German economist Johann von Thünen, who maintained an estate in Mecklenburg, noted that:

> the space of land which can be mown in a day by one labourer, depends very much on the strength of the Corn itself, and the expense of mowing ought on this ground, to be calculated rather in proportion to the quantity of produce, than to the extent of the surface . . . . the expense of binding and shocking depends, like that of mowing, rather on the quantity of the produce than on that of the land.[27]

Judge Peters, in the eighteenth century, remarked that American reapers could reap a much larger area each day than English reapers because of the lighter American yields.[28] Gervase Markham, in his treatise on husbandry written in the seventeenth century, stated that while a man and a binder should reap 1 acre per day of a standard wheat crop, they could reap 1.25 acres of thin wheat. Also a mower could cut

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[22] A. D. Hall, *The Book of the Rothamsted Experiments* (London, 1919), pp. 35, 55, 63, 72, 84, 93.

[23] Hall, *Rothamsted Experiments*, p. 55.

[24] Henry Stephens, *The Book of the Farm* (Edinburgh, 1844), vol. 2, p. 116.

[25] Albert Thaer, *The Principles of Agriculture* (London, 1844), vol. 2, p. 407; J. R. McCulloch, *A Statistical Account of the British Empire* (2nd edn., London, 1839), p. 466.

[26] This figure assumes the reaper cuts a three-foot-wide swath through the grain.

[27] Jacob, *Tracts*, Second Report, p. 89.

[28] George Washington, *Letters to Arthur Young and John Sinclair* (Alexandria, 1803), p. 75.

2 to 2.5 acres of a standard crop of barley or oats per day, but 3 to 4 acres of a thin or short crop.[29]

A nice illustration of the near constancy of reaping labor per bushel when yields varied is found in Bolton Priory during the great famine between 1315 and 1317, when yields fell drastically. The average gross output of corn at Bolton during these years was 40 percent less than the average in the years from 1310 to 1314, principally because yields per acre fell. Payments to reapers fell by 42 percent between the two periods, or about proportionately to output. On the home farm the actual man-days expended in reaping were recorded, and these fell by 40 percent in the famine.[30]

An early study of the effects of manures upon wheat crops contains data showing that as the yield increased, the number of sheaves of straw increased proportionately.[31] In Scotland and the north of England reapers were often paid by the sheaf of corn reaped, not by the acre, so that the price paid per acre could vary by a factor of two, depending on the bulk of the crop.[32] Similarly, in both Prussia and Hungary in the early nineteenth century reapers were often paid by a share of the sheaves, not by the number of acres reaped.[33] In a village in the north of India in 1984 the method of payment for reaping wheat and barley was one sheaf in twenty cut, though yields per acre varied by a factor of three to one across different fields.[34]

The other important characteristic of threshing and of reaping is that the labor input seems to have been independent of the relative cost of labor and grain. It was possible to extract a little more grain per acre by applying more labor, but the possibilities here seem to have been limited. Grain prices in Britain would vary greatly from year to year, but nominal wages were fairly stable, so that real wages were low in years of bad harvests. On average in the ten-year intervals from 1701 to 1841 the highest corn price was double the lowest, yet the payment for threshing and reaping did not change with the price fluctuations, implying that in years of high prices the threshers did not thresh more carefully to extract a few more ears of corn. Threshing payments show similar stability in medieval England. John Howlett noted that in abundant harvests the wheat crop could be double the size of bad years, and that the amount of labor expended in threshing the crop would vary correspondingly.[35] Since there was little else to do for most of the winter but thresh the grain crop, if extracting more grain was possible by careful threshing, it would be expected that the amount of labor expended in threshing would vary little with the size of the crop. The many farming handbooks do not contain any advice to vary threshing and reaping rates with the relative prices of grain and labor.

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[29] Gervase Markham, *Markham's Farewel to Husbandry* (14th edn., London, 1683), p. 113.

[30] Ian Kershaw, *Bolton Priory: The Economy of a Northern Monastery, 1286–1325* (Oxford, 1973), pp. 38, 50.

[31] J. C. Morton, *A Cyclopedia of Agriculture* (Edinburgh, 1855), vol. 2, p. 1144.

[32] Stephens, *Book of the Farm*, vol. 2, pp. 335–37; Morton, *Cyclopedia*, vol. 2, p. 1145.

[33] Thaer, *Principles*, vol. 1, p. 102.

[34] Private communication from Aktil Gupta.

[35] John Howlett, "The Different Quantity and Expense of Agricultural Labour in Different Years," *Annals of Agriculture*, 18 (1792), p. 570.

Nor is there evidence that workers in Eastern Europe were threshing or reaping more carefully. William Jacob, comparing continental threshing and reaping practices to British ones, concludes of northwest Europe that the corn was "less firmly bound in sheaves, and less cleanly thrashed out."[36] He complains of the poor performance of agricultural work in Poland where "it appeared to me that a much greater proportion of the grain was left among the straw, than in that which has passed under an English flail."[37] It was reported that the corn from Eastern Europe exported to Britain had to be rescreened to exclude the large amounts of foreign material left in the grain.[38]

The gains from more careful threshing are hard to calculate, but seem to have been small. Threshing machines were valued in part because they could thresh cleanly, and sometimes exact figures were given about how much more grain they extracted. In England in 1796 straw threshed by machine yielded 2.5 percent more grain than straw threshed by hand.[39] The grain left in the straw, however, was not lost but served as pig feed. This leaves very little possible gain from careful threshing even where wages were low.

Two-thirds of the labor inputs in grain farming, including the key operation of harvesting, had labor inputs per bushel of output which were largely independent of the yield per acre and the cost of labor. Medieval and Polish peasants should only have needed as much labor per bushel for these operations as American farmers in the early nineteenth century. Yet the grain output of these workers was only one quarter or less than outputs per worker in the American northeast. Consequently medieval English peasants and Polish peasants either took large amounts of leisure, or they worked at much slower rates. Below I show that it was differences in the rate at which simple manual tasks were performed which largely account for the differences in output per worker across countries in the early nineteenth century and over time.

LABOR INTENSITY

Threshing grain was the most important winter occupation in arable agriculture, representing about 17 percent of the arable labor input in the three-field system. Hand threshing, an ancient technique, was carried on in essentially the same fashion in all of northern Europe and the northern United States in 1800 as in 1300. Until the threshing machine, the only advances in technique were in methods for separating the grain from the chaff. But winnowing was always a minor part of threshing labor. As Thaer notes of flails, the jointed wooden stick used to beat the corn on the barn floor, "none of the modifications, either in their make or of the manner of using them, are of sufficient importance to render it worth while to take the trouble of endeavouring to teach the labourers to perform the operation in any way to which they are unaccustomed."[40] Since threshing was indoor work, it was independent of local topography or climate. The labor required per unit of grain output did depend in part on the ratio of grain to straw: with more straw, more labor was required. But, as is noted above, as yields increased the proportion of straw to grain stayed constant or even increased. Grain mown with a scythe required more labor than that reaped with a sickle, since with mowing there was more straw, and it was not so tightly bound. But the differences appear to have been small, about 10 percent according to one author. And in any case mowing was more common in high-wage areas so that threshing rates in high-wage areas are if anything understated.

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[36] Jacob, *Tracts*, Second Report, p. 29.

[37] Jacob, *Tracts*, First Report, p. 28. It is not entirely clear whether Jacob is discussing free or serf labor.

[38] Jacob, *Tracts*, Second Report, p. 18.

[39] John Boys, *A General View of the Agriculture of the County of Kent* (London, 1796), p. 59.

Table 1 shows for a series of locations in the early nineteenth century the winter day-wage of agricultural laborers, in dollars per day and in bushels of wheat at the local prices, as well as the bushels of "wheat-equivalent" which would be threshed per day (in the time taken to thresh a bushel of wheat, roughly 1.75 bushels of barley could be threshed and 2.25 bushels of oats), calculated in two ways. The first is to divide the day-wage by the payment per bushel to threshers, who received a piece rate. The second is to estimate a normal day's threshing in each area, using agricultural handbooks and the observations of visitors. The first method generally gives a lower rate than that estimated directly, since the earnings of threshers on piece work were greater than the standard winter day-wage.

It is clear that the time taken to perform this simple task varied by a factor of about three or four to one. Threshing rates and the money wage were highly correlated, as Figure 1 shows, and the correlation holds if we measure the wage in terms of wheat, but the threshing rate seems to have determined the day-wage rather than vice versa.

Before the nineteenth century most of the evidence on threshing rates is from the medieval period, since manorial accounts recorded both yearly payments to manorial servants such as ploughmen and payments per bushel for threshing and winnowing various grains. Table 1 also shows the calculated threshing rate for the years before the disruptions

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[40] Thaer, *Principles*, vol. 2, p. 386.

TABLE 1
THRESHING RATES, 1820–1850

Region	Winter Wage ($/day)	Wage (bushels of wheat at local price)	Threshing Rate (day wage/ payment per bushel)	Threshing Rate (direct estimate)
United States				
North	$0.67	0.68 bu.	6.1	8.0
United Kingdom				
North	0.43	0.28	5.3	
South	0.36	0.24	3.8	6.0
Ireland (1800–10)	0.22	0.10	3.2	
Belgium (1869)	0.25	0.16	2.5	
Germany				
East Freisia	0.21	0.34	4.7	
Sleswick	0.14	0.18	2.9	
Holstein	0.14	0.18	2.8	3.9
Mecklenburg	0.12	0.16	2.6	4.3
Prussia (1812)	0.11	0.09	2.0	
Other areas	0.14	0.13	2.0	
Denmark	0.11	0.14	2.3	3.1
Austro-Hungary				
Bohemia	0.11	0.16	2.2	2.3
Carinthia	0.19	0.25	2.5	2.6
Styria	0.15	0.19	2.5	2.6
Moravia	0.11	0.14	1.0	2.2
Poland	0.08	0.14	2.2	
Russia				
Podolia				2.8
Medieval England (pre-1349)		0.11	2.8	

Notes: The threshing rates in the last two columns are in bushels per man-day. Where the length of the day is not specified, it is assumed to be eight hours, since threshing was largely a winter operation. In Podolia the threshing rate is for serfs with oxen. Using oxen, output per worker would be much greater than using only manual labor.

Sources: Leo Rogin, *The Introduction of Farm Machinery in Relation to the Productivity of Labor in the Agriculture of the United States in the Nineteenth Century* (Berkeley, 1931), pp. 176–80, 229–35; *Gardener's Chronicle and Agricultural Gazette*, 27 April 1850, pp. 266–67; Hugh Raynbird, "On Measure Work," *Journal of the Royal Agricultural Society of England*, 7 (1846), pp. 119–40; Great Britain, Parliamentary Papers, *Royal Commission on Agriculture*, 1881, vol. 16, 758–59; William Jacob, *Tracts Relating to the Corn Trade and Corn Laws: including the Second Report* (London, 1828); W. Jacob, *A View of the Agriculture, etc., of Germany, and parts of Holland and France* (London, 1820); Albert Thaer, *The Principles of Agriculture* (London, 1844), vol. 1, pp. 61, 102; Jerome Blum, *Noble Landowners and Agriculture in Austria, 1815–1848* (Baltimore, 1948), pp. 187–91; William Jacob, *Notices Respecting the Commerce of the Black Sea* (London, 1826), pp. 54–58.

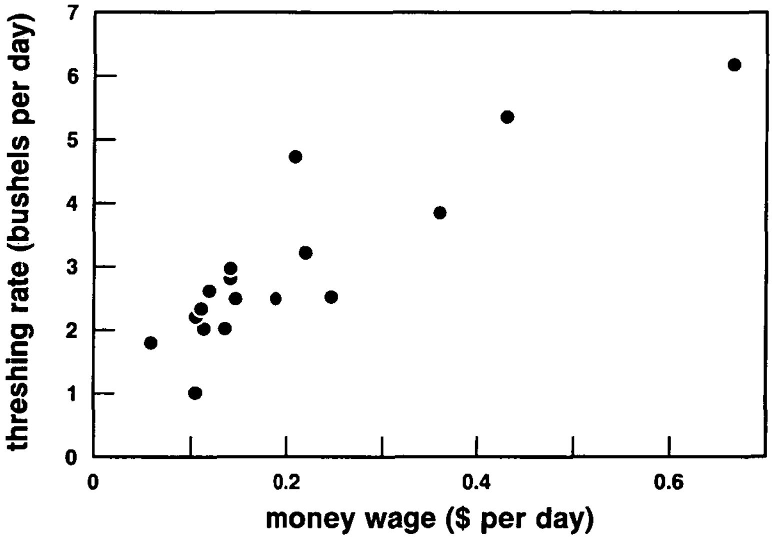

FIGURE 1
THRESHING RATES VERSUS THE MONEY WAGE

Source: See Table 1.

of the Black Death in 1349, which was 2.8 bushels per day.[41] This implies that medieval English threshers performed their task at only 44 percent of the American rate and at from 51 to 71 percent of the rate in Britain in the nineteenth century. But the threshing rates in medieval England were roughly the same as in nineteenth-century Germany and somewhat higher than in some areas of Eastern Europe.

Reaping, like threshing, was an old technique which varied little between countries. The reaper would stoop to cut handfuls of stalks that he or she had gathered, using a short, smooth or serrated, crescent-shaped knife. Other workers would follow the reapers to bind and shock the cut stalks. No animals and very little machinery were involved. But again there were great differences in the amount of grain that a worker could harvest in a day in different regions in the early nineteenth century, and between then and medieval times. Table 2 shows the number of bushels of wheat one worker reaped per day, either as given directly by commentators or, as in Table 1, calculated from the wage and the price paid for reaping an acre of wheat. Once again the workers in America did the most work per day, the British were next, and the rate of work in Eastern Europe or in medieval England was much slower.

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[41] This figure is for manors whose labor accounts are recorded in James E. Thorold Rogers, *A History of Agriculture and Prices in England* (Oxford, 1866), vol. 1, pp. 245, 288–89; vol. 2, pp. 273–310, 329–34. Similar data for Ramsey Abbey and Crowland Abbey show threshing rates of 2.37 bushels, and 2.74 bushels per day, prior to 1349. See Frances M. Page, *The Estates of Crowland Abbey* (Cambridge, 1934); and J. Ambrose Raftis, *The Estates of Ramsey Abbey* (Toronto, 1957).

TABLE 2
BUSHELS OF WHEAT REAPED PER WORKER PER DAY

Region	Year	Assumed Yield per Acre (bushels)	Reaping Rate (day wage/ payment per bushel)	Reaping Rate (direct estimate)
Italy	1st cent. A.D.	(7.2) bu.		(3.2)
England	1261–1349	9	2.8	
England	c. 1300	9		3.6
Russia: Podolia	1826	16.5		3.2
Austria: Styria	1836	(18)		(3.6)
Hungary	1850	(15)	3.4	
Germany: Berlin	1812	16	4.0	8.0
Britain: North	1850	26	10.1	
South	1850	26	8.1	
Suffolk	1846	26	10.7	8.7
United States:				
North	1820–1837	21.2		12.2

Notes: The reaping rate is in Winchester bushels per worker per day. Parentheses around a number indicate that the figure is particularly tentative. The harvest work-day is assumed to be 12 hours long where the number of hours is not specified.

Sources: K. D. White, "Wheat Farming in Roman Times," *Antiquity*, 37 (1963), pp. 207–12; K. D. White, "The Productivity of Labour in Roman Agriculture," *Antiquity*, 39 (1965), pp. 102–7; James E. Thorold Rogers, *A History of Agriculture and Prices in England* (Oxford, 1866), vol. 2, pp. 273–310; Dorothea Oschinsky, *Walter of Henley and other Treatises on Estate Management and Accounting* (Oxford, 1971), p. 445; William Jacob, *Notices Respecting the Commerce of the Black Sea* (London, 1826), pp. 54–58; Jerome Blum, *Noble Landowners and Agriculture in Austria, 1815–1848* (Baltimore, 1948), pp. 188–190; Albert Thaer, *The Principles of Agriculture* (London, 1844), vol. 1, p. 103, vol. 2, p. 405; *Gardener's Chronicle and Agricultural Gazette*, 27 April 1850, pp. 266–67; Hugh Raynbird, "On Measure Work," *Journal of the Royal Agricultural Society of England*, 7, 1846, pp. 125, 139; Leo Rogin, *The Introduction of Farm Machinery in Relation to the Productivity of Labor in the Agriculture of the United States in the Nineteenth Century* (Berkeley, 1931), pp. 125–26, 229–35.

I noted above that the crucial constraint on output per worker in grain agriculture was the work rate in harvest, since the labor demand peaked sharply for a few weeks at harvest time. The reaping-rate figures derived in Table 2 fit well with the figures above derived independently on the amounts of grain produced per worker in each area. If we consider America, Britain, Bohemia, medieval England, and Poland, the amounts of grain produced per worker were in the ratios 4.4: 3.1: 1.9: 1.3: 1.0, while the bushels of wheat reaped per day were in the ratios 3.8: 2.8: 1.1: 0.9: 1.0.[42] This would suggest that most of the differences in output per worker across regions and across time stemmed not from differences in techniques but from differences in work rates.

THE DETERMINANTS OF LABOR INTENSITY

Why should there be such great variations in the work rate? I can conceive of four types of explanation for low labor intensity in Eastern

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[42] I use the reaping rate for Podolia as a proxy for that in Poland.

Europe and in medieval England: the methods of labor recruitment and supervision were inefficient; the workers did not know how to improve their performance; the preferences of the workers were different; or the workers were trapped in an equilibrium where poor nutrition made the workers inefficient, which kept wages low, and consequently nutrition poor. I cannot explore these possibilities in detail here, but I can show that some of the above explanations appear inconsistent with the historical record.

Eastern Europe and medieval England were alike in being servile societies, where the peasants were bound to deliver labor services to the lord and were constrained by many other restricting and demeaning exactions. North America was a society where most wage laborers in agriculture were in the process of accumulating capital to operate their own farm, and where wages were so high and land so cheap that most could easily accomplish their goal. I am skeptical, however, of these organizational features as the basis of the labor-intensity differences. For a start, almost all the work-rate estimates in the sections above are for wage workers, not for bound labor. In both medieval England and Eastern Europe, large amounts of labor, particularly for threshing, were hired and paid piece rates so workers had every incentive to work quickly. Second, the agricultural workers of northern Britain were more efficient than those of southern England and Ireland, and of Western Europe, though their social situation was essentially similar, as were the hiring and supervision practices.

Were low-productivity areas locked into an equilibrium where poor nutrition, because of low wages, created low productivity and consequently low wages? Traditional agriculture did involve large expenditures of energy; could workers in areas of low wages not afford the food required for effective labor? Notice that such an explanation implies that farmers in poor areas were systematically ignoring cheap ways of increasing the productivity of their workers. Since feeding workers on the farm was common, farmers could easily ensure that workers were fed adequately for high work rates. In 1862 farm workers in northern Britain were paid \$0.57 per day, those in the south \$0.47.[43] But those in the North, as was well known to agricultural commentators of the nineteenth century, performed more work per day than those of the South. One set of piece-rate prices and wages suggests that northern workers did 45 percent more per day than those of the South.[44] If southern workers had done as much as those in the North, the employers would have saved \$0.21 per worker per day. Edward Smith's dietary survey of 1862 suggests that northern workers were consuming about 1,000 more calories per day than those in the South. If the constraint in the South was a lack of calories, it could have been lifted very profitably, since the cost of 1,000 calories in the southern diet was only about $0.04. It seems unlikely, therefore, that low productivity areas were constrained by poor nutrition, at least for the methods of labor organization used in nineteenth-century Europe.

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[43] Great Britain, Parliamentary Papers, *Sixth Report of the Medical Officer of the Privy Council, Appendix 6: Food of the Lowest Fed Classes*, vol. 27, 1864, pp. 216–329.

[44] *Gardener's Chronicle and Agricultural Gazette*, 27 Apr. 1850, pp. 266–67, and 30 Apr. 1860, pp. 392–93.

The same sources show Irish workers in 1862 were paid only $0.25 per day, and their work rate was about half that of northern Britain. Yet they consumed nearly as many calories per day as those highly productive workers and about 900 calories per day more than the southern workers, who did about 31 percent more work per day than the Irish. The Irish diet was monotonous and unattractive, consisting mainly of potatoes, maize when potatoes were not available, and yoghurt, but it was both cheap and well supplied with calories and protein.

Some might argue that the changes in work rates over time, and the differences between countries, were caused by very low-level learning, but by knowledge differences nonetheless. Workers in advanced areas knew better techniques or organized the work better. The problem here is that the manual tasks examined above had been performed over a very long period of time in northern Europe. Threshing, for example, was done in essentially the same way in 1850 as in 1250. It was not a task requiring a large team of workers, or careful coordination of the elements of the process. In each country in each year for these 600 years most of the labor force spent many winter days at this strenuous and repetitive task. Yet despite the millions of independent and potentially innovating threshers, only a favored few countries discovered superior methods to shorten the exhausting labor. And those countries happened to be ones where other manual tasks were performed rapidly.

It appears more plausible that the people in the low-productivity areas were different from the people we are familiar with. Either they worked little or they exerted themselves little when at work (that is, they had different tastes) or their mental life is otherwise alien to us. They were not merely people like us who happened to be lacking certain pieces of knowledge.

IMPLICATIONS

If the threshing and reaping rates in Tables 1 and 2 are representative of work rates in these regions, then increasing the Polish work rate to the American would have increased wages per worker by 220 percent (measuring wages in terms of wheat). Giving Poland the land abundance of the United States and the same technology would have only increased Polish wages by 50 percent. Similarly, medieval English wages would have been increased by 190 percent by adopting American work rates, but wages would have increased by only 110 percent by having the land abundance and technology of the United States in the early nineteenth century. The major cause of high wages in the United States in the early nineteenth century was faster work rates. While the importance of technical change in economic growth is not disputed, this finding does imply that in writing the history of agriculture before the mechanization of the late nineteenth century we have tended to overplay the role of technological change as a source of growth. Labor was the major input in agriculture, either direct or embodied in land improvements. If the time taken to perform simple tasks could vary by three to one or more, then there was ample room for productivity growth before 1850 without any technical change. And until the machine age, much of the rise in the productivity of British agriculture seems to have come from some such source.[45]

The large variation of work rates in agriculture in the early nineteenth century finds echoes in a cross-country comparison of the cotton textile industry in the early twentieth century. In cotton textiles the number of machines per worker varied remarkably from region to region, by amounts as large as or larger than the variations observed in agriculture, though workers were operating the same types of machines running at nearly the same speeds.[46] There are also indications in cotton textiles that not all productivity growth in the nineteenth century was a result of technical change. A lot of the productivity increase was not associated with specific mechanical innovations, but with workers operating more machines.

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[45] Elsewhere I calculate that while productivity rose by over 50 percent in British agriculture between 1661 and 1841, the amount of increase that was attributable to technical progress was only about 15 percent, the rest coming from more labor inputs per worker and more intense work. See Clark, "The Agricultural Revolution in Britain."

[46] See Gregory Clark, "Why Isn't the Whole World Developed? Lessons from the Cotton Mills," this JOURNAL, 45 (Mar. 1987), pp. 141–74.